

AD-772 976

INVESTIGATION OF PROTECTIVE COATINGS  
FOR AMMUNITION COMPONENTS-TIMING  
MOVEMENTS OF MECHANICAL TIME FUZE

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Philadelphia, Pennsylvania

June 1973

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Originating Activity (if separate address)

FRANKFORD ARSENAL  
Philadelphia, PA 19137

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

INVESTIGATION OF PROTECTIVE COATINGS FOR AMMUNITION COMPONENTS -  
TIMING MOVEMENTS OF MECHANICAL TIME FUZE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Memorandum Report

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE

June 1973

7a. TOTAL NO. OF PAGES

13

7b. NO. OF REFS

None

8a. CONTRACT OR GRANT NO

AMCMS Code: 4932.05.6202.05

8b. PROJECT NO

9a. ORIGINATOR'S REPORT NUMBER(S)

Frankford Arsenal Memorandum Report  
M73-14-1

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned  
this report)

10. DISTRIBUTION STATEMENT

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1385 Department of Commerce  
Springfield VA 22151

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

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13. ABSTRACT

Inorganic coatings were applied to components of Mechanical Time Fuze M564 for the purpose of improving corrosion resistance. The coatings studies were 5mm or less in thickness and included:

- Chromate or anodize coating for aluminum components;
- Electroless nickel, chromate, or immersion tin coating for brass components;
- Electroless nickel or electroless cobalt coating for ferrous metal components.

Coated components were compared to uncoated in basis metal corrosion when exposed to salt spray or simulated tropical environment.

Assembled timing movements of bare and coated components were exposed to simulated or real tropical environment and tested for functional operability. None of the mechanisms functioned properly after only four weeks' exposure; in most instances, malfunction was attributed to sticking of pallet lock slides resulting from corrosion of small Mallory metal lever weights.

D FORM 1473  
1 NOV 66

REPLACES DD FORM 1473, 1 JAN 66, WHICH IS  
OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

16

UNCLASSIFIED

Security Classification

14

KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

Mechanical Time Fuse

Timing Movements

Corrosion Prevention

Electroless Plating

Tin Immersion Deposition

Chromating

Anodizing

Frictional Properties

Tropical Exposure

Galvanic Corrosion

Mallory Metal

Salt Spray Exposure

UNCLASSIFIED

Security Classification

**MEMORANDUM REPORT M73-14-1**

**INVESTIGATION OF PROTECTIVE COATINGS  
FOR  
AMMUNITION COMPONENTS**

**Timing Movements of Mechanical Time Fuze**

**by**

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**AMCMS CODE: 4932.05.6202.05**

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**June 1973**

## **ABSTRACT**

Inorganic coatings were applied to components of Mechanical Time Fuze M564 for the purpose of improving corrosion resistance. The coatings studies were 5 $\mu$ m or less in thickness and included:

- a. Chromate or anodize coating for aluminum components;
- b. Electroless nickel, chromate, or immersion tin coating for brass components;
- c. Electroless nickel or electroless cobalt coating for ferrous metal components.

Coated components were compared to uncoated in basis metal corrosion when exposed to salt spray or simulated tropical environment.

Assembled timing movements of bare and coated components were exposed to simulated or real tropical environment and tested for functional operability. None of the mechanisms functioned properly after only four weeks' exposure; in most instances, malfunction was attributed to sticking of pallet lock slides resulting from corrosion of small Mallory metal lever weights.

## INTRODUCTION

Timing movements of mechanical time fuzes are normally packed into airtight M2A1 ammunition boxes. Some movements are also sealed within their housings with O-rings, and desiccant cartridges are employed to keep the humidity of the entrapped air at a low level. In spite of these precautions, movements are known to malfunction occasionally as the result of corrosive action having taken place. Such attack may result from opening of the ammunition box with intention to use for firing - moisture can then come in contact with those movements, particularly those that are not sealed within their own housings. The presence of even minute amounts of corrosion products at critical locations of the movement can result in malfunction of the mechanism.

It is the objective of this study to ascertain the corrosion resistance of movement components and to determine the feasibility and effectiveness of applying protective coatings to the components. The coatings to be applied must be less than about 5  $\mu\text{m}$  (0.2 mil) thickness in order to maintain components within dimensional requirements. Electroplated coatings are not candidates because they are generally nonprotective at this thickness and there is a tendency for excessive buildup at projections and edges of complex-shaped components.

On the other hand, deposits produced by autocatalytic chemical reduction (electroless plating) are quite protective because of exceptionally low porosity, and are readily applied very uniformly over complex-shaped components. Of particular interest in this regard are the electroless nickel or cobalt coatings.

Coatings by electrochemical displacement (immersion deposition) or by surface conversion (chromating or anodizing) will also be considered since they are uniformly applied and thin coatings can be quite protective.

## EXPERIMENTAL PROCEDURES

Movement components and, in some instances, subassemblies of the M564 mechanical time fuze were exposed to five percent neutral salt spray for 24 hours or to simulated tropical\* conditions for a 21-day period, and then examined for signs of corrosive attack.

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\*Tropical room: 29° C and 95% RH for 20 hours; 26° C and 100% RH for 4 hours.

Protective coatings were applied to components (or subassemblies) as follow:

1. Electroless nickel plating of ferrous metal or brass - immersion for 20 minutes at 85° C in 25 g/l  $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ , 9 g/l  $\text{NaC}_2\text{H}_3\text{O}_2$ , 22.5 g/l  $\text{NaH}_2\text{PO}_2 \cdot \text{H}_2\text{O}$ , 1.0 mg/l  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$ ,  $\text{pH}$  4.7; to deposit 4 to 5  $\mu\text{m}$  (0.16 to 0.20 mil).
2. Electroless cobalt plating of ferrous metal or brass - immersion for 20 minutes at 70° C in 25 g/l  $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ , 25 g/l  $\text{Na}_2\text{C}_4\text{H}_4\text{O}_4 \cdot 6\text{H}_2\text{O}$ , 15 g/l  $\text{Na}_2\text{SO}_4$ , 4 g/l  $(\text{CH}_3)_2\text{NHBH}_3$ ,  $\text{pH}$  5.0, to deposit 4 to 5  $\mu\text{m}$  (0.16 to 0.20 mil).
3. Chromating of brass - immersion for 15 seconds at 25° C in 7.5 g/l Iridite 17P,\* 0.5 ml/l  $\text{HCl}$  (37%).
4. Immersion tin deposition of brass - immersion for 3 minutes at 45° C in 19 g/l  $\text{SnCl}_2$ , 188 g/l  $\text{NaCN}$ , 22.5 g/l  $\text{NaOH}$ .
5. Chromating of aluminum - immersion for 2 minutes at 25° C in 7.5 g/l Alodine 1200S,\*\* 1.3 ml/l  $\text{HNO}_3$  (sp gr, 1.42).
6. Anodizing of aluminum - anodize 15 minutes at 21° C at 1.3 A/dm<sup>2</sup> in 15 percent (wt)  $\text{H}_2\text{SO}_4$ ; sealed by immersion for 5 minutes at 85° C in 50 g/l  $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$ .

The coated specimens were subjected to laboratory test conditions (salt spray and tropical room) for evaluation of corrosion resistance.

Friction measurements were made on flat aluminum or brass components in the as-received, alkaline cleaned, or coated condition. A modified Bowden-Leben type apparatus was used, with tests conducted at 24° C with 100-gram load on 1/4 inch diameter steel ball and a sliding speed of 2.4 cm/min.

Twenty-eight movements were disassembled, and components and subassemblies were coated as shown in Table I.

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\*Allied-Kelite Products Div., Baltimore, MD

\*\*Amchem Products Div., Ambler, PA



**Table I.**  
**Coatings Applied to Movement Components and Subassemblies**

<u>Group (quadruplicate)</u>	<u>Coating Applied</u>			
	<u>Aluminum Components</u>	<u>Brass Components</u>	<u>Ferrous Metal Components</u>	<u>Brass-Ferrous Metal Subassemblies</u>
A	-	-	-	-
B	Chromated	-	-	-
C	Chromated	Electroless nickel	-	-
D	Chromated	-	Electroless nickel	Electroless nickel
E	Chromated	Electroless nickel	Electroless nickel	Electroless nickel
F	Chromated	Electroless cobalt	Electroless cobalt	Electroless cobalt
G	Chromated	Immersion tin	-	Immersion tin

The coated components and subassemblies were reassembled and tested for ability to function satisfactorily. The movements were then exposed, without housing but shielded from falling material, to tropical room conditions for a four-week period and then retested for ability to function effectively.

Five fuze timing movements were tested to demonstrate ability to function satisfactorily and then placed on exposure for a seven-month period in a hut at the Fort Sherman Panama Canal Zone rain forest. The movements were exposed without housings but shielded from direct contact with falling debris. After exposure, the movements were again tested for their ability to function effectively.

### RESULTS AND DISCUSSION

#### Corrosion of Components

Individual components of the M564 mechanical time fuze movement were exposed to salt spray conditions and examined after a 24-hour exposure period. Few components withstood the exposure without formation

of corrosion products. All of the aluminum components had considerable amounts of white corrosion products over the exposed surface, with somewhat more on the cast than the wrought material. There was evidence of dezincification and some powdery blue-white corrosion products on exposed brass components. The ferrous metal components proved to have a wide variability in corrosion behavior. Most of the ferrous metal components were rusted to some degree, which ranged from slight to considerable. The uncorroded components include the various coiled springs (stainless steel or cadmium plated steel), lug (class 301 stainless steel), and escapement spring (class 302 stainless steel). The rusted components were purportedly of passivated, corrosion resisting steels of various classes.

Disassembled movement components were exposed to simulated tropical rain forest conditions for a 21-day period. All aluminum components had isolated spots of powdery white corrosion products. Small amounts of powdery blue-white corrosion products were formed upon brass components. Most of the ferrous metal components were not affected by the exposure. Only the following components were found to have rusted significantly:

- Arm, Firing (Class 410 stainless steel)
- Shaft, Firing Arm (Class 416 stainless steel)
- Screw, Bottom Assembly (Class 416 stainless steel)
- Collar (Class 416 stainless steel)
- Timing Disc Assembly

It is thus evident that many components of the movement cannot resist exposure to high humidity, even under nonsaline conditions, without formation of significant quantities of corrosion products which are considered to greatly increase the probability of malfunction of the mechanism in service. The aluminum components appear to require the greatest attention for improved corrosion resistance, but protection of brass and some ferrous metal components is also indicated.

Corrosion Resistance of Coated Aluminum Components - Chromated or anodized aluminum components were exposed to salt spray for a 24-hour period and to simulated tropical environment for a 21-day period without producing any evidence of corrosive attack. Either of the coatings provide effective protection, but only the chromate coating will be considered for future tests because of the simplicity and low cost of production application.

Corrosion Resistance of Coated Brass Components - Chromated, immersion tin deposited or electroless nickel plated brass components were resistant to corrosive attack during the exposure to salt spray or tropical room environments.

Corrosion Resistance of Coated Ferrous Metal Components - Electroless nickel plated ferrous metal components were fairly resistant to corrosive attack during tropical room exposure with only traces of rust evident on some specimens after a 21-day period. However, the electroless nickel deposit provided only moderate protection to the same components exposed for 24 hours to salt spray; some of the components had almost as much rusting evident as unplated components. The electroless nickel coating, at the deposit thickness employed (4 to 5  $\mu\text{m}$ ), thus appears suitable for protection of the ferrous metal components exposed to nonsaline humidity conditions but not to salt exposures.

Electroless cobalt deposits (4 to 5  $\mu\text{m}$  thickness) on the ferrous metal components provided complete resistance to basis metal attack at either salt spray or tropical room exposures. The cobalt deposits are thus more effective than nickel for providing effective corrosion resistance. However, the cobalt surface tarnished badly during exposure, though the tarnish layer appeared quite thin and adherent and is not likely to produce adverse effects on the ability of the mechanism to function. Nevertheless, it was considered advisable from the esthetic standpoint to reduce or eliminate the tendency for tarnishing of the cobalt surface. It was found that ten-second immersion at 25° C in either 10 g/l Alodine 1200S or 200 g/l  $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$  - 6 ml/l  $\text{H}_2\text{SO}_4$  (sp gr, 1.84), followed by rinsing and drying, effectively retarded the tendency for tarnishing of electroless cobalt to occur during exposure to the test environments.

Galvanic Corrosion of Aluminum in Contact with Brass - Whereas chromated aluminum components were found resistant to corrosive attack, it was considered necessary to determine whether corrosion resistance would be maintained when in galvanic contact with brass. In the assembled movement, aluminum and brass plates are in intimate contact and their positions in the EMF series are so far apart as to indicate the probability of adverse effects on corrosion resistance of the more active member, i.e., aluminum. Chromated aluminum plates (2nd Lamina - Plate No. 2) were assembled with brass plates (1st Lamina - Plate No. 2) that had been chromated or electroless nickel plated. In both instances there was only slight corrosion of the aluminum; chromated aluminum in contact with bare brass was badly attacked. It was thus demonstrated that, for aluminum to

be protected against corrosive attack, it is not only necessary to provide a chromate film, but brass in galvanic contact must either be chromated or electroless nickel plated.

### **Corrosion of Dissimilar Metal Subassemblies**

It is considered inadvisable and nonpermissible to apply protective coatings to assembled components except under extraordinary circumstances, because faying surfaces will be inadequately protected and solutions can become trapped. However, a number of the components used to make up the movements were available only in small subassemblies and it was thus necessary to apply protective coatings to the subassemblies for corrosion resistance evaluations. Most of the subassemblies consisted of ferrous metal and brass components.

It can be recognized that the necessity to coat brass-ferrous metal assemblies tends to restrict the coatings that can be applied because the coating system may be applicable to only one of the metals. For example, chromating of the brass components of subassemblies left the ferrous metal components in a corrosion-susceptible condition. Thus, while chromating of brass might normally be a desirable treatment, it was impractical to apply this treatment to subassemblies which included ferrous metals.

It was found, however, that the immersion tin deposition treatment applied to the subassemblies provided significant protection to the ferrous metal components, although the treatment is specific for brass and not applicable to ferrous metals. The protection of steel components was particularly marked when a substantial proportion (50 percent or more) of the exposed surface area consisted of brass. It is postulated that the ferrous metal is coated with a thin, protective tin film by a galvanic mechanism during the coating of brass in intimate contact with the ferrous metal.

Subassemblies coated with electroless nickel deposits were found to be inadequately protective, particularly at crevices formed by the junction of components. On the other hand, electroless cobalt coated subassemblies were quite resistant to corrosive attack, even at crevices. The reason for the differences in behavior of electroless nickel and electroless cobalt is not known.

## Frictional Properties

The coefficients of friction of aluminum or brass components in the as-received, alkaline cleaned, or coated condition are shown below.

<u>Metal and Treatment</u>	<u>Coefficient of Friction (<math>\mu</math>)</u>
Aluminum	
As-received	0.18
Cleaned	0.33
Cleaned and chromated	0.48
Brass	
As-received	0.17
Cleaned	0.36
Cleaned and chromated	0.50
Cleaned and electroless nickel plated	0.18
Cleaned and electroless cobalt plated	0.17
Cleaned and immersion tin plated	0.33

The coefficient of friction of aluminum and brass was found to increase rather drastically simply by cleaning of the metal surface. The components used for these tests had not been lubricant-treated but, apparently, oily residues are present from handling or condensation from the atmosphere. Chromating of the aluminum or brass resulted in substantial increase in the coefficient of friction. The electroless nickel or electroless cobalt surfaces were substantially lower in friction coefficient than the cleaned substrate before plating. The immersion tin deposit had little effect on the frictional property of the cleaned brass surface.

## Exposure and Testing of Assembled Movements

When coated components and subassemblies were reassembled and tested for functional effectiveness, all but Group E (see Table I) functioned satisfactorily. Group E, which represents four movements whose components were all electroless nickel plated (except for the aluminum components which were chromated) failed to run at all. The reason for failure is not known but it is believed that the nickel coatings may have caused critical dimensional tolerances to be exceeded.

The other movements were exposed in the tropical room for a four-week period and then retested for their ability to run properly. After the exposure, Groups A, B, C, and G movements failed to run at all. Examination revealed that, in all of these movements, the pallet lock slide had become "frozen" because of a substance that had "exuded" from the tiny lever weights during exposure and migrated to the pallet lock slide region. The lever weights were determined to be Mallory metal (powder metallurgy tungsten alloy). When the Mallory metal lever weights are exposed to cyclic humidity conditions, a heavy liquid is produced on the surface which is strongly acidic and which, when dried, forms a tenacious, hard, resin-like material. It is believed that the material produced is an unusual form of corrosion product. It should be pointed out that lever arms used for previous corrosion resistance testing had no weights attached, which is the reason the poor resistance of the Mallory metal was not discovered earlier.

One of the objectives of this study was upset by the functional failure of the movements owing to "corrosion" of the lever weights before it could be ascertained whether protective coatings applied to the various components would prolong the life of fuze timing movements during environmental exposure.

The movements of Group D were found capable of running, but behaved erratically and the running time was shorter than normal; one unit ran only three seconds. The brass components were unprotected in these units and corrosion products were evident on the brass surfaces that might have contributed to failure to run properly. There was also some corrosion of the lever weights though the amount of "corrosion" products observed was limited owing to the protective influence of the electroless nickel coating.

The movements of Group F (aluminum components chromated; balance electroless cobalt plated) ran better than any of the other groups, but the runs were shorter than normal. The components were uncorroded and even the Mallory metal lever weights were effectively protected by the cobalt deposit. Thus, the reasons for failure of this group to run properly were not evident from examination of the components. An apparent lack of lubricant at bearing surfaces was noted which might indicate that periodic condensation of moisture resulted in dissipation of lubricant. If this should prove to be the case, the use of dry film lubricants is indicated for movements subjected to such exposures.

## Exposure of Movements in Tropical Rain Forest

All movements that had been exposed to the Panama Canal Zone rain forest conditions for a seven-month period were found incapable of functioning at all. Examination of the disassembled units revealed that the pallet lock slides of all movements had become immobile from the migration of corrosion products originating at the Mallory metal lever weights. Other than on the Mallory metal, there was surprisingly little evidence of corrosive attack, with merely traces of corrosion products visible on some aluminum, brass, and ferrous metal parts.

## CONCLUSIONS

Most of the movement components of M564 mechanical time fuze are unable to withstand exposure to salt spray for 24 hours or to simulated tropical rain forest for 21 days without the formation of significant quantities of corrosion products on the surfaces. Effective corrosion resistance is achieved by the application of a chromate or anodic coating to aluminum components. Chromate, immersion tin, or electroless nickel coatings applied to brass components or electroless cobalt coatings applied to ferrous metal components also provide effective protection against corrosive attack.

Galvanic corrosion of chromated aluminum in contact with brass during salt exposure is minimized when the brass is either chromated or electroless nickel plated.

Movement subassemblies of brass and ferrous metal components are effectively protected against corrosive attack by electroless cobalt plating or by immersion tin deposition. However, the latter is effective only when the exposed area of brass is equal to or larger than that of the ferrous metal.

Standard M564 mechanical time fuze movements are unable to function at all after exposure to real or simulated tropical environment owing to "corrosion" of Mallory metal lever weights with formation of products that prevent movement of pallet lock slides. Movements whose components are effectively protected against corrosive attack are able to run but are sub-standard in performance after four weeks' exposure to simulated tropical rain forest environment.

## RECOMMENDATIONS

Mallory metal lever weights should not be used in mechanical time fuze movements unless adequately protected against the formation of "corrosion products" that prevent operation of the mechanism.

All aluminum and brass components should be chromated as a simple, inexpensive means of providing improved corrosion resistance. However, tests should be conducted to ensure that the frictional properties of chromate films do not adversely affect functionability of the mechanisms.

Corrosion-resisting steel components that were found to have poor corrosion resistance should be replaced by a more resistant alloy or protectively coated.

The study described herein should be continued, with the purpose of determining the ability for standard movements to withstand various types of exposure and to determine the causes of movement malfunction when Mallory metal lever weights are not present in the system. Coatings should be applied to those components indicated to require additional protection.